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ADDRESS

OF

ASHBEL WELCH, President, A. S. C. E.,

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I do not propose this evening to undertake any general survey of the engineering field. For such a survey, I refer you back to Mr. Chanute's address of two years ago. I shall not attempt to glean after him. But I shall speak of several disconnected subjects of present interest, and give some reminiscences showing the contrasts between the past and the present; and in such reminiscences I shall disinter the buried memories of some of the great engineers of the past.

When we look around on the engineering works recently completed,

or now in progress or in contemplation, the first thing that strikes us is their extraordinary magnitude.

Prominent among them is the St. Gothard Tunnel, passing for 48 900 feet, or more than nine and a quarter miles, through the base of the great Alpine chain which has hitherto been so formidable a barrier between southern and central Europe, a thousand feet below the vale of Urseren and the villages of Andermatt and Hospenthal, and 6 500 feet, or a mile and a quarter below the eternal snows that cover the crest of the mountain. The cost was about $12 000 000 ; or nearly $250 per foot lineal. This tunnel is nearly 9 000 feet, or a mile and two thirds longer than the Mt. Cenis tunnel, by far the longest previously built.

Such stupendous works have been made practically possible by the compressed air drill, and the high explosives now used. In my active engineering days, rocks were drilled for blasting only by the power of human muscle, either by one or two men churning a hole in the rock with a heavy rod some six feet long, or by one man holding and slowly turning a short drill, and another man driving it into the rock with a sledge hammer. Then came the steam rock drill, then the compressed air drill. The compressed air not only does the work, but it ventilates, and its sudden expansion cools, the tunnel or the mine where it is used.

The first, or one of the first tunnels in this country in which the rock was drilled by compressed air, was the Nesquehoning, by Mr. J. Dutton Steele. Since then many have been made by the same means, one of the most memorable of which is the Musconetcong tunnel, a mile long, made under the direction of Mr. Robert H. Sayre. This difficult work gave occasion for the valuable treatise on tunnels by Mr. Drinker, who was in immediate engineering charge of it. The Hoosac Tunnel, 24 000 feet long, after a long-continued struggle, was completed several years ago, and is now in use.

Among the tunnels now being constructed, is one half a mile long under the plateau of West Point ; and another 4 000 feet long through the hard trap rock of Bergen Ridge, at Weehawken ; both on the line of the road now in construction on the west shore of the Hudson. Nearly all the debris from the latter is raised through shafts.

The project is now under serious consideration of making a tunnel some 21 miles long under the straits of Dover. A few years ago such a project would have received only a laugh of incredulity.

The admiration of the world has not yet abated for the boldest of arched bridges yet built, that over the Mississippi at St. Louis ; with its

steel arches of 500 feet span, its piers of heavy masonry sunk to solid rock more than a hundred and thirty feet below the high water surface of the river, through shifting sands, and during the most fearful floods.

The Brooklyn Bridge—1 595 feet or nearly a third of a mile long, over an arm of the sea more crowded with commerce than any other in America, and high enough to allow a line of battle ship to sail under it—is drawing to completion, and will be (though perhaps only for a few years, 'till something more stupendous comes), one of the wonders of the world.

Probably the boldest plan for a bridge ever proposed, is that now in contemplation over the Forth, at Edinburgh, but of which it is yet premature to speak.

Many very long spans and important bridges are now in progress in this country, such as the one over the Missouri by Mr. Morrison, but time does not permit even a glance at them.

We are now so familiar with the success of suspension bridges for railroads, that we can hardly realize the almost universal disbelief in that success before they were tried. The late John A. Roebling told me before his bridge was finished, that Robert Stephenson had said to him, "If your bridge succeeds, mine is a magnificent blunder." And yet, unexpectedly to the best engineers in the world, the suspension bridge over the Niagara answers the purpose quite as well as the tubular bridge over the St. Lawrence.

The mention of the St. Lawrence reminds us of the great and interesting improvement of that river now going on under the direction of Mr. Kennedy. The original low water channel between Quebec and Montreal, had, in places, a depth of only 11 feet. Now they are increasing the low water depth to 25 feet, with a width of 300 feet. The work is done with bucket and chain dredges, exceedingly well adapted to the purpose. Some of the buckets are armed with great steel teeth which excavate the solid rock (geologically Utica slate, but compact rather than slaty in its structure), detaching and bringing up blocks sometimes containing several cubic feet.

If anything of the kind could astonish us in this fast moving age, it would be the rapidity with which, during the past half dozen years, the construction of elevated railroads in New York, and to some extent elsewhere, has gone on. It is of little use to find their aggregate length, for in a few weeks any such estimate must be corrected. There may now be about thirty-three miles of such roads, all double track. The average

cost, including stations and equipment, has been about $800 000 per mile.

One of the cases in which a new contrivance effects a great revolution, is that of the elevator. This has been in use for perhaps a quarter of a century at the Continental Hotel in Philadelphia, and in a few other places, but is now coming into general use, and is revolutionizing the mode of building in our great cities, especially in New York. A block of buildings is not now extended along a street as formerly, but is set up on end, and the highway to the different houses or parts of the block, is not horizontally along the sidewalk, but vertically through the elevator shaft. Sky room is cheaper than earth room. It is said that a lot on the corner of Wall and Broad streets was recently sold for over $320 per square foot, or at the rate of $14 000 000 per acre! Equal to the surface covered with silver dollars 5 deep. These stupendous buildings will give engineers and architects much to look after in the way of foundations.

This reminds us of the Holly plan, in limited use elsewhere for several years, now going into extensive use in the City of New York, of dispensing with private fires for heating, and private boilers for generating steam; and furnishing heat and steam power for a considerable district from one great central set of boilers, piled boiler over boiler, tier on tier, for 120 feet in height. This is one of the operations most characteristic of the present time. Nothing is to be done now by the individual, but everything by some institution, or corporation, or central power, or great firm. Man has ceased to be a unit, and become only an atom of a mass. With the disappearance of the things themselves, the dear old phrases "family fireside," and "domestic hearth," are rapidly disappearing.

Mr. Shinn and the Engineer, Mr. Emery, have kindly given me some particulars respecting this transportation of heat and power, but I can only refer to one or two points. The first and most obvious necessity is to prevent the escape of the heat. This is done by enclosing the steam-carrying pipe in a small brick tunnel, with a flat cover on the top; and filling the space around the pipe, from the bottom of the tunnel to the flat covering above, with mineral wool, which is found to be an excellent non-conductor. It is made by blowing a jet of steam into a stream or jet of melted furnace slag. The arch and covering of the tunnel are plastered over with asphaltum, to exclude all moisture. The loss of heat is said to be very small. One of the great difficul-

ties comes from the expansion and contraction of the pipes, the range being more than an inch in a hundred feet. This is provided for by making the end of each section of about 80 or 100 feet, terminate in very flexible diaphragms of thin copper, the diaphragms being supported by stiff iron ribs.

Among the great enterprises in contemplation, is the interoceanic canal, or the interoceanic railroad for large ships. This is not the occasion for expressing any opinion on any of the competing projects. I will only say that if the world is determined to have a sea level canal, it makes a great mistake in not getting fuller information about the San Blas route.

Many things that have been done by this generation seemed beforehand far less possible than the successful working of the ship railway proposed by Captain Eads. The difficulties are certainly very great, but we can see how they may be overcome. The real question is, whether, taking into account the expense of overcoming those difficulties, the construction and operation of such railway will be more economical in the end than the construction and operation of some one of the proposed canals.

The last year has been one of intense activity, particularly in railroad construction. A year or two ago money was so abundant, and, therefore, interest so low, and so many capitalists, great and small, were tired of letting their money lie idle, that new enterprises of many kinds were started, especially new railroads, and enlargements of capacity of those already in use. As the money market has approached its normal condition, some of the new projects have been dropped.

It is instructive to look back and trace the connection between the progress of railroads and the financial condition of the country.

From the year 1787 there has been a financial catastrophe, or at least depression, in our country regularly every ten years down to the year 1857. The cause of this seems to be rather psychological than anything else. It seems to have taken the American business mind just ten years to pass through the various stages and degrees of panic after the financial crash, through extreme cautiousness, great cautiousness, moderate cautiousness, moderate confidence, great confidence, extreme confidence, recklessness, and then another crash.

These decennial depressions were modified by circumstances. That of 1817 was intensified by the effects of the war of 1812 and by the failure of the crops of 1816. That of 1837 was moderated by the efforts

of the United States Bank, and part of its effects postponed until the final failure of the bank a few years later, which produced the intercalary depression of 1842. The effects of the crash of 1847 were moderated within two or three years by the discovery of the gold in California.* The crash of 1857 was intensified by the previous inflation from the gold excitement, the rapid railroad construction in the West stimulated by the land grants, and its effect continued longer than usual on account, first, of the apprehension, and then the reality of civil war.

The effects of a financial crash do not appear in the statistics of railroad construction till a year or two after it takes place, for if a road is well advanced towards completion, it will probably soon be finished, even during a panic. This is shown in the statement following.

In consequence of the financial troubles of 1841–2 the mileage of new railroads opened in 1843 and 1844 fell off 71 per cent. below that of the two preceding years. Before the panic of 1847 had time to reduce the increase of mileage its effects were more than counterbalanced by the discovery of gold in California and by the land grants. After the great crash of 1857 the new mileage in 1859 and 1860 fell off 57 per cent. below the average of the three preceding years.

During the four years of the war the new mileage was 64 per cent. less than that of the four preceding or of the four succeeding years.

Notwithstanding the excitement and inflation after the close of the war, the periodicity of the financial intermittant was broken, and no crash occurred in 1867. The causes are too recent and too well known to require mention. Besides the influx of money from the sale of our government bonds abroad, the ocean telegraph hastened the equalization of interest on both sides of the Atlantic, and the flow of money to the points where it was wanted. A few years ago the normal rate of interest in the West was 50 per cent. higher than in the East. Now there is but little difference. The depression was postponed till 1873.

From the close of 1867 till the close of 1874, when the effects of the panic of 1873 became visible in the statistics of railroad extension, more than 4 400 miles of railroad per annum were opened, twice as much as the yearly average of any similar period had been before. For the next three years (1875, '6 and '7) the annual increase fell off 69 per cent. below the average of the preceding seven years.

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* That discovery was first made in digging the foundation or the tail race of Sutor's Mill, by James W. Marshall, who fifteen years before had been a boss on work going on under my direction, and whose three sisters are still neighbors of mine.

The troubles that followed the panic of 1873 were entirely different from those that followed any of the decennial or other panics previous to that time. They were financial; this was commercial. In all the earlier cases the difficulty was want of money, in this last case there was, or soon came to be, a plethora of money. Those were convulsions, this was stagnation. There were more means of production and of transportation than there was demand for. If wealth consists of such means, then the community were suffering from excess of wealth.

The railroads opened in the United States January 1, 1880, aggregate 86 500 miles in length, being 40 per cent, of all the railaoad mileage of the world. Last year we had 93 600 miles, and this year we have just about 100 000 miles. But mere length is a very inadequate measure of their magnitude. The terminal mile of some roads has probably cost as much as five hundred miles of some other roads. At one time, and possibly now, the cost per ton taken, on the first two miles of the road from New York to Pittsburg, was more than the cost of carrying that ton over the next two hundred miles. The increase in aggregate magnitude of all the roads may be almost as much in the enlargement without increase in length of the old, as in the extension of the new. We hear in more than one case of thirty miles of additional terminal tracks being laid at one point.

The diminished plethora of money, and the greater caution now apparent, will, it is to be hoped, moderate the increase of the means of production and transportation beyond the demands of consumption, so as to prevent another stagnation.

The investment in railroad property in the United States is set down at about 5 000 millions, perhaps about one-eighth of the value of all the property of the country, real and personal.

When we speak of the extraordinary magnitude of the engineering works of the present day, we do not forget the pyramids, temples, and fortifications of Egypt and Chaldea. Some of them exceeded in magnitude anything that has been made since. What makes it more strange is, that the force that produced them was almost entirely human muscle, while now the work is done largely by steam directed by human brain. Two contrasts strike us as we look at the ancient and modern: the one was executed by slaves and conscripts, with little or no compensation; the other by free men, glad to work for the compensation offered. The old was for the glorification of the few; the modern for the use of the many.

The stagnation that followed the breakdown of 1873, and the consequent low rates of transportation, compelled the managers of railroads to reduce the cost to a point previously thought unattainable, by increasing the power of the engines and the weight of the trains, by more convenient arrangements, by more service of the machinery, by cheaper construction and repairs, by better machinery and organizations of labor, and many improved appliances for handling, and by the stoppage of leaks generally.

American engineers and managers have often shown that *poverty* is the mother of invention. For example, they used cross ties as a temporary substitute because too poor to buy stone blocks, and so made good roads because they were not rich enough to make bad ones. American engineers are, or at any rate, were trained on short allowance of money. As that is the best engineering which accomplishes the purpose at the least cost in the long run, American engineering ought to be of the best.

It is doubtless the fertility of resource coming from the necessity of effecting much with little means, which has created a demand for American engineers in other parts of the world. A few years ago the Government of British India sent for an American engineer, and the first thing they asked him to do was to report on their railroads from the American point of view. Our lamented past president, W. Milnor Roberts, was employed by the Government of Brazil, as I judge from what happened after he went there, to train their engineers, educated in European schools, in American modes and ideas.

Among the greatest of the projects of the present day is the improvement of the Mississippi River.

Towards it the eyes of our profession and of the whole country have of late been anxiously turned. It has overflowed an extent of territory of more than 20 000 square miles, and destroyed millions on millions of property and hundreds on hundreds of lives. One of the most important engineering problems of the age is how to restrain its ravages, as well as to improve its navigation.

In order better to understand what the Mississippi River Commission is doing for these purposes, let us glance at a few of the principles which, or some of which, doubtless control the action of that commission. Those principles are very simple, though their application is often very difficult.

The quantity of solid matter of greater specific gravity than water

that a running stream is capable of carrying in suspension, other things remaining equal, increases with the increase, and decreases with the decrease, of the velocity of the stream. Like most cardinal principles, this is so simple and obvious that it seems ridiculous to state it.

It follows, from this, that when a stream is loaded with such matter up to its carrying capacity, then, other things remaining the same, if the velocity is decreased, it will drop part of its load, and if the velocity is increased, it will, if suitable material is in contact with the current, take on more load,

Mathematicians have calculated that the difference in velocity between parallel films of moving water keep the particles of solid matter afloat; but, as is obvious to the eye, and as Mr. Francis has proved, running water does not move in parallel films, and it is also obvious to the eye that the suspended matter commonly moves more or less up and down. The real motion is a compound of parallel and ricochet movements, combined in all sorts of ways and proportions, the boiling and plunging movements increasing with the velocity, the unevenness of the bottom and sides of the channel, and the presence of foreign objects and aquatic vegetation, and being greater in proportion to the whole volume of the water when that is shallow. It is largely this boiling movement which raises the solid matter and keeps it afloat. With the same velocity, the greater it is, the greater the capacity of the stream to carry such matter. Some of the causes, however, which produce the boiling motion may diminish the velocity, and so, on the whole, diminish the transporting capacity.

This is one reason why the exact relation between velocity and transporting capacity is so difficult to determine.

The same current will raise and carry a greater weight of small than of larger particles of the same form and material; for the impact of the current against the particle, tending to move it, is as its surface, that is, as the square of its linear dimensions, while the weight and consequent resistance to motion is as the cube of the same dimensions. Flat particles are carried more easily than round or cubical, for they have more surface in proportion to weight. Of course a particle of greater specific gravity, as of trap rock, is harder to move than one of the same form and size of less specific gravity, as anthracite. It takes eight times the force to raise a particle of specific gravity 3, in water, that it does to raise one of the same size of specific gravity 1¼. This shows why, in many cases, a higher velocity carries no more weight of solid matter per cubic foot of

water than a lower ; the higher velocity and greater boil take up larger and heavier particles than the lower, and a much larger amount of transporting capacity is used up in carrying them than in carrying an equal weight of finer and lighter particles.

This is another reason why the exact relation between velocity and transporting capacity has not been ascertained ; the sizes and specific gravity of the particles transported are not known, and therefore their effect on total quantity transported is not known.

This relation might perhaps be found by some such experiments as the following : 1st. Grind some suitable kind of stone of uniform substance to fine powder ; then, by sifting, separate the particles of the powder or dust into lots according to size, each of uniform fineness ; then see how much weight of each of these sizes per cubic foot of water can be carried in suspension at the same velocity. 2d. Make the same experiment with stone of different specific gravity, sorting it into lots of the same sizes, the water being kept at the same velocity. 3d. Try the same things with different velocities. The facilties for doing all this can probably be found at some cement mill.

The specific gravity of the bank furnishing the silt, or of the bar formed by it, or of the sediment deposited from the water, gives no information of the size of the particles, and little of their specific gravity. Hence the transporting power with the same velocity appears so different in different observations. Total weight gives only partial information.

I should expect that the transporting power would be as the square of the velocity. I have washed out bars of heavy sand by temporarily confining the current over them, and its power of removing the sand seemed to be about as the difference in level of the water above and below, that is, as the square of the velocity created by that difference.

Though the weight of solid matter per cubic foot of water carried near the bottom is often but little more than near the surface, it is commonly much coarser, and therefore uses up much more transporting capacity. The velocity near the bottom is also less. From each of these circumstances, especially from both together, it follows that the transporting capacity is much greater near the bottom, where the boiling motion is greatest, and where the difference in the velocity of the films of water is the greatest, than near the surface.

It is sometimes said that the transporting capacity with any given velocity is inversely as the depth. This cannot be so, for it would lead to

the absurd conclusion that, with the same velocity, a stream a foot deep is capable of carrying as much silt in the aggregate as a stream a hundred feet deep.

If a stream runs over a soft uniform bed for a sufficient length of time, it will become charged with the maximum quantity of solid matter due to its velocity, its depth, its boil, and to the size, shape and specific gravity of the particles taken up by its current. If there is not suitable material within reach of its current, it will carry less than its maximum. As before pointed out, aggregate weight of silt alone is a very imperfect measure of transporting capacity. The maximum load with the same velocity may perhaps be two or three times as great with one material as with another.

If a stream carrying its maximum quantity of silt widens as you go down stream, so that, when the water is high, its section becomes greater than that of the stream above, the velocity decreases there, and a deposit takes place. The coarsest particles will drop first, and thus the bar formed is likely to be hard. When the water subsides, so that the area over the bar becomes less than that of the deeper water up-stream, the declivity of the surface must be increased in order to get the increased velocity necessary to pass the water through the smaller area, and that raises the surface above the bar, deadens the current up-stream, and causes a deposit to take place in the deeper water above. Thus the tendency of expansions of a stream beyond its normal width is to raise its bottom not only there, but everywhere, and consequently to increase the height of its floods.

If, on the other hand, a wider place is contracted to the normal width of the stream, the velocity will be increased so as to cut out the bar, if the material of which it is composed is not too hard. By making the channel of uniform width, and keeping it regular and even, the bed, if soft, will be lowered, and the height of floods diminished. With a given discharge, the greater the depth, the less is the fall required; or, with the same fall, a less area. A memorable example of the deepening effect of the contraction of a stream to the regular width is by the South Pass Jetties.

The tendency of the greater velocity to take up and carry off solid material is illustrated at bends of rivers. The swiftest water is near the concave shore, that side of the channel is in consequence deepened and the more rapid current eats into that shore. The current on the convex

side is slackened and a deposit takes place. Hence a crooked stream has a constant tendency to become more crooked.

It has always been a wonder why an eddy current was more erosive than a direct current. My theory is, that when the water turns from its direct course and curves round toward the shore, the centrifugal force separates and throws off a part of the coarser particles held in suspension (just as in old times when a farmer threw a shovel full of mixed wheat and chaff, the heavier wheat went beyond the chaff), and thus the current being now deprived of part of its load, its power of erosion is partially restored, and it cuts the bank rapidly.

The Mississippi River approximates the conditions of such a stream as I have described.

The first thing done to improve it, is, to make its channel as uniform as possible by contracting its wide expanses. This is done by placing a continuous line of brush matresses or screens along each boundary of the modified channel, the edge of the mattress next the channel being sunk to the bottom with stone, the edge farthest from the channel being buoyed up to the surface of the water. The silt-bearing water filters slowly through the mattress, and the current being deadened, drops its sediment and soon forms a bank under and behind the mattress. This new bank is protected from erosion by the inclined face of the mattress. In floods, the current goes over the mattresses into the bays outside, where the velocity being slackened the silt is deposited, the bays are gradually filled up, and dry land ultimately forms between the line of the mattresses and the original shore. Confining the current increases the velocity and deepens the channel between the lines of the mattresses, a uniform channel is established, the bed of the stream is lowered, the water being deeper less declivity of surface is required, the water surface is lowered, and the overflow in floods moderated.

When running water washes the foot of a vertical bank, suppose for example 60 feet high, and washes out a narrow groove along its face, suppose a foot deep, and then the overhanging mass falls so as to leave the bank still vertical, the quantity that falls into the stream is 60 cubic feet per foot lineal of the stream. The finer part of this will be carried down stream, the coarser will probably gradually work down to the bottom and raise the bed. Thus the capacity of the river will be diminished and the height of the surface and of the floods increased. But if the water of the same stream washes a foot horizontally into a bank sloped one to one, and the overhanging weight falls so as to leave the back of

the step thus made vertical, the quantity thus thrown into the stream will be only half a cubic foot per foot lineal.

Hence the absolute necessity of sloping the banks of the Mississippi where they are steep and unprotected. The commission are forming this slope by the use of the water jet, and protecting it until the rootlets and willows cover and protect it, by a slight covering of brush.

The great forces of nature, though they cannot be resisted, may often be guided and controlled by means that seem the feeblest. The magician of science is to control the mighty Mississippi with the willow wand.

If a stream of uniform section, bearing its maximum load of silt, *and confined within its banks*, is furnished with an additional channel, then though each channel may take its proportion of the silt brought down from above, the reduction of velocity consequent on the increased aggregate sectional area, will cause a deposit to take place below the bifurcation, the bed of the original channel will be raised and its capacity diminished. Hence a bar is likely to form below an extensive crevasse.

But if a stream overflow its banks, then the water that would otherwise run overland may be carried off by additional outlets, so that they do not lessen the velocity of the main stream, below the point of diversion.

The principles that govern such cases are mostly plain enough, but owing to many disturbing circumstances, their application is often very difficult. A thousand cases may arise where opposing tendencies operate, each tendency with imperfectly known force, about which no man can form an intelligent opinion without an intimate knowledge and careful study of the circumstances, and careful weighing of the force of the opposing tendencies.

I have stated those principles and their application not because hydraulic engineers will find anything new in the statement, but to bring them to the attention of such dry land engineers as may not already have considered them.

I think no apology necessary for dwelling so long on this subject, for there is no other so opportune, no other more important.

To this generation it seems almost ridiculous to mention turnpikes as ever having been of any interest. And yet the City of Philadelphia retained for a time its commercial ascendency by them, especially by the great Lancaster turnpike. If I rightly remember the language of the

geography I studied when a boy, it somewhat exultingly described this turnpike as "seventy-two miles long, four rods wide, and covered, wide enough for two wagons to pass, with eighteen inches of pounded stone." It was over this highway that the wealth of the interior poured into the commercial metropolis of America, in Conestoga wagons.

The National roads from Washington and Baltimore into Ohio, made by the Federal Government are famous for their share in settling some of the important constitutional questions of our government. One great party disputed the power of Congress to use the nation's money for any such purpose. The contest was long and fierce, but Congress, with much misgiving, made the appropriations. When a few years ago they appropriated $15,000 for the improvement of the Kiskiminitas, they must have got bravely over such misgiving.

Though canal engineering is a thing of the past, its history is instructive. In England it commenced 120 years ago, the first engineer being James Brindley, a millwright. He seems to have known little of what had been done before, and his plans were evidently original. When he proposed to build an aqueduct across the Irwell for the Duke of Bridgewater's canal, his critics said they had often heard of castles in the air, but they never heard before where they were to be put. Brindley built several canals, on one of which was a tunnel a mile and a third in length. He was succeeded in canal making by such men as Telford and Smeaton and Rennie. Though uneducated, he gained the admiration of scientific as well as practical men. When he wished to study a subject thoroughly, he "laid in bed to contrive," as he expressed it. The secret of his success, therefore, evidently lay in concentration of attention on the subject in hand, and he kept out of the way of anything that could distract his attention.

The era of canal building in England was rather less than seventy years; between 1760 and 1830.

During the last decade of the last century, several efforts were made to connect the detached navigable reaches of some of the rivers in this country, by means of short canals and locks. One of those was undertaken at Richmond under the inspiration of General Washington. Another was at Philadelphia, around the Falls of the Schuylkill. But the one of special interest in the history of engineering, was at Little Falls on the Mohawk.

The great thoroughfare between the City of New York and the West and Northwest was up the Hudson and through the valley of the

Mohawk. The transportation through that valley was partly by three, five, or seven-horse teams over the Genesee Turnpike,* and partly by boats on the river. Those boats were like what on the Delaware we used to call Durham boats, which were 8 feet wide and 60 feet long, drawing, when loaded, a foot or two, and carrying from 10 to 20 tons. They were pushed up stream by two or four men with setting poles held against the shoulder, and kept in their course by the captain with a long steering oar.

At Little Falls the descent of the river is over forty feet, and, of course, the boats could not pass, but their cargo was carried by the portage of two miles, to other boats above or below. To avoid this the canal and locks were built. They were finished in 1794. Jedediah Morse (father of S. F. B. Morse, of telegraphic fame) published his great standard American Gazetteer a few years later, and in it he quotes the following expression of the public sentiment of the time: "The opening of this navigation is a vast acquisition to the commerce of this State." It was conjectured that these locks (which a man could almost jump across), and similar "great works" west of them, might soon make the little town of Albany the capital of a great empire.

The Mohawk continued to be the principal artery of commerce from New York to the interior, until the opening of the Erie Canal in 1825.

Mr. Weston, "that haughty British engineer," as an old gazetteer calls him, was brought over from England to build the locks at Little Falls and elsewhere. One of his assistants was a land surveyor of Rome, New York, named Benjamin Wright, or Judge Wright, as he was called. When, years afterwards, it was decided to build the Erie Canal, Judge Wright, though having only the slender experience he had acquired under Weston, was appointed chief engineer. The skill and good judgment which was shown by this father of American engineering, the few errors into which he and his still more inexperienced assistants fell, the great effects produced by them with the means at their command, and the adaptation of their works to the circumstances of the time, are absolutely wonderful.

One of Judge Wright's principal assistants was Canvass White. His skill early brought him into notice, and he was sent by the State of New York to England to learn what he could, especially about hydraulic

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* The migration to the West (which then meant the Genesee country) was over this turnpike in horse or ox teams; the patriarch of the family and his wife having on their shoulders the same black and white coverlet, and the big brass kettle full of dishes hanging under the hinder axletree of the wagon. Some of their grandchildren now sit in the high places of the nation.

cement. Despairing of getting it at any reasonable price, and of making it stand the voyage, then from four to ten weeks, he set himself on his return to finding or making a substitute for European cement.

Led partially by the geological position of the hydraulic limes in England, and partly by what was known of their composition, he explored and tested certain rocks of Western New York, and made the first discovery of hydraulic cement in America. The State of New York gave him ten thousand dollars for his discovery. Subsequently he discovered or recognized cement rock in Pennsylvania in the way till then unknown, but now so familiar, by the contact of limestone and slate.

And yet how soon those men, once so widely known, are forgotten. An eminent and excellent engineer, who had paid especial attention to cement, lately told me he never heard of Canvass White.

One of Judge Wright's assistants, but much younger than Canvass White, was John B. Jervis, whose name to-day is one of the most honored on the rolls of this society.

Many of the distinctive characteristics of American engineering originated with those Erie canal engineers. We practice their methods to-day, though most of their very names are forgotten. As a class, they wrote little. There were then no engineering papers prepared, and no engineering societies to perpetuate them, if they had been prepared. They were not scientific men, but knew by intuition what other men knew by calculation. Judge Wright's counsel was "as if a man had inquired at the oracle of God." What science they had, they knew well how to apply to the best advantage. Few men have ever accomplished so much with so little means.

The mention of cement reminds us of quite a new use of it, lately, under the direction of Mr. Chanute. The Erie road crosses the Genesee river by a high viaduct just above a fall. The bed of the river was wearing away, and would soon destroy the viaduct. An artificial bottom of cement has stopped the wear.

The Erie canal was opened in 1825. Gov. Clinton passed through in a boat on one corner of the deck of which stood a cask of water from Lake Erie, on another corner a cask of water of the Hudson. Gov. Clinton limped from the boat to the public halls, and speeches were made by and to him; and it was a great glorification. The result justified the public expectation. It built up the City of New York, and settled

the question of commercial supremacy between that city and Philadelphia.*

The success of the Erie canal soon brought about the construction of many others. They were thought to afford the most economical means of transportation, and railroads were made, not to carry goods to the final destination, but to a canal or other navigation. After the success of the Liverpool and Manchester Railway in 1830, this opinion was seriously shaken, and in a short time canal construction mostly ceased. Its era in this country was scarcely a quarter of a century, between 1817 and 1835.

Canals to be successful now must be capable of passing vessels of large capacity, must not have too much lockage, and the locks must be worked by steam or water power ; the boats must be moved by steam, either on board, when the vessels are large enough, or, when the vessels are smaller, by locomotive on the bank, or by cable at the bottom, and then the locks must be large enough to hold the fleet taken by one locomotive or cable tower; there must be plenty of water, and the canal must connect harbors or navigable waters.

I tried towing by locomotive on the canal bank more than forty years ago. There is, of course, no difficulty in one engine towing several boats, but if the locks are not largs enough to pass the whole fleet at once, the delay of all the fleet till each boat is passed separately, counterbalances the economy of steam instead of horse power. The speed even for light boats cannot be increased to more than five or six miles per hour on account of the wave.

Cable towing, notwithstanding the reported failure on the Erie canal, can, with proper boats and apparatus, and with experienced men, be easily performed on the crookedest canal in America, as it is now done in Belgium.

Canal engineering does not avail itself of the engineering resources of the age. Little improvement is made in it : mainly, I suppose, because it is not considered worth improving.

The most remarkable early river improvement in this country was that of the Lehigh.

About the year 1817, Josiah White and Erskine Hazard commenced the improvement of this river, and made other preparations to inaugurate the anthracite coal trade. In 1820 they sent to market 365 tons,

*An old pilot once told me that in his younger days there were three or four ships out of Philadelphia to one out of New York.

which was the beginning of the regular anthracite coal trade of America. Now the annual amount will soon reach 30,000,000 of tons.

The descending navigation they made consisted, first, in clearing the channel of rocks, and confining the water in the rapids, when low, to that narrow channel by boulder wing dams ; second, when the fall was too great for this, in building dams with bear trap locks ; and third, in storing the water in pools, and letting it run only when the coal arks were running.

The bear-trap locks have given the hint for several devices since used, and are well worthy of examination. Near each end of the lock was a pair of gates, each gate reaching across the lock and to the back of the recess on each side, which gates, when not damming back the water, lay flat on the bottom of the lock. The lower gate could be made to revolve through an arc of somewhere about 40 degrees around a horizontal axis coincident with its down-stream edge. The upper gate of the pair, when laid flat, lapped over about half of the width of the lower gate, and revolved through a similar arc around its upstream edge. When laid flat, the water, of course, ran freely over them. They were raised by admitting the water under them from the pool above the head of the lock, through the side wall, when the pressure of water pressed them up. They were prevented from going too far by shoulders in the recesses. The gates then came within 10 or 15 degrees of being at right angles to each other, the under side of the upstream gate resting on the upstream edge of the downstream gate. They could be held in any position, so as to hold back the water entirely, or let it run over with more or less volume, as required. The arks containing the coal were commonly shot through over the partly raised gates as over so many dams.

Such locks, copied from those on the Lehigh, are now in use on the Ottawa, at the Canadian capital. Many of us at our last convention were shot through them on rafts.

It is well worth inquiry whether these bear-trap gates would not be the best possible, and possibly the cheapest, for letting the water rapidly out of a reservoir for scouring purposes. A full stream could be set running in a few seconds, and the flow could be regulated with perfect ease, and stopped at any moment.

In many rivers it is desirable to dam the stream back at low water, and let it run freely at high water. In Belgium, on the Meuse, they use needle dams for this purpose. Another probably better adjustable dam is in use in France. The bear trap gates, with proper appliances, on a

solid platform at the bottom of a river, would enable a man on shore to raise a dam across that river, or if raised, to lower it to the bottom, in a few minutes.

I have used this contrivance for a fish sluice in a permanent dam, by which the water ran freely through the sluices when necessary, and at other times was retained at full height.

The coal, on the descending navigation of the Lehigh, was sent to market in arks consisting of six boxes, 16 feet square and 20 inches deep, coupled by hinges, the whole carrying about 100 tons.

Of course, it oftened happened in that hazardous navigation that the arks were wrecked. The lumps of hard coal were soon rolled down-stream by the current to some shoal below, where they were found in the form of completely rounded boulders.

In making these improvements, eight hundred men were employed at once near Mauch Chunk, then in the wilderness, quite outside of the bounds of civilization. It was not easy to control these men, many of whom, doubtless, had never been remarkable for good order. The sheriff of the county was unable to make an arrest. But the fertile genius of Josiah White, and the strong good sense of Erskine Hazard, soon found a remedy. Under their inspiration the men organized themselves into a a republic, adopted a code of laws, which their backwoods poet put into rhyme, and these laws, which they themselves had made, were strictly enforced and universally submitted to. Punishment was inflicted by a good stout hickory stick, as big as your finger, well laid on with a strong arm.

The chief executive of this republic, called the lieutenant, was also the executioner. When all hands were called to witness punishment, they said or sang the part of the law which had been transgressed, and the lieutenant beat time on the offender's back. One of the gravest offenses was for a man to take more on his plate, or his shingle, than he could eat. Punishment of this soon stopped the grabbing, and the provision bills were very much reduced. At any official announcement, the expression of loyalty to the supreme authority, was not as in England, "God save the King," or as in Pennsylvania, "God save the Commonwealth," but "Hurrah for Mr. White and all the rest!"

Engineers and employees may well take a hint from this piece of history.

Josiah White, the Pennsylvania Archimedes, as he was sometimes called, invented, among many other things, the drop gate so valuable in canal locks of moderate rise. In 1827, he and Hazard built the Mauch

Chunk Railroad, nine miles long, the first railroad (except a little tram road at Quincy granite quarries) ever built in America. My hap was to ride on it within a few weeks after it was opened.

In the early times of the coal business, the same coal passed in succession through several hands, each of whom had an interest distinct from the rest. The owner of the land, the mine operator, the owner of the lateral road to the canal, the canal company, the boatman, the tide water vessel owner, and the coal merchant, must each make a profit, or he would stop, and that would stop all the rest, though, taken all together, the profits made by some would greatly counterbalance the losses made by others. Hence, those parties who performed all the operations, succeeded best, for they always kept on and made something, while those who took the different steps of the business in succession were stopped, because some of them made nothing. Thus, the latter were driven to consolidate, though often against their earlier intentions. The owners of coal roads bought large tracts of coal land, not to monopolize, but to insure a constant stream of transportation, at times when private owners are accustomed to stop, because there is no profit in their branch.

This generation wonders how the business of the world ever could be carried on, and especially, how railroads ever could be run, without the telegraph. And yet many of us remember when there was none. And after it was shown that information could be sent by an electric current through a wire, it was years before any one made use of it.

About fifty years ago, Professor Henry made a series of brilliant discoveries in electro magnetism, one of which was, that by means of a current through a wire, a signal could be made and information given (by ringing a bell, for example), a long distance off. Years afterwards, Steinheil, Morse, Wheatstone and others, applied Henry's discovery to the actual conveyance of information; Morse's apparatus, as it seems to us Americans, being by far the best. The wonder to us now is, why Henry himself did not apply his discovery, and why others did not sooner do so. The answer is found in a very important phase of human mind. The habit of mind into which the scientist is liable, perhaps likely, to fall, is to look at scientific result as his ultimate end. Such result arrived at, the same habit of mind is to use it only to attain further scientific result. Hence, men of science so rarely are benefited pecuniarily by their own researches. Hence, also, it frequently happens that engineers who have kept at their studies without practice till too

late in life, are so often less successful than those of far less science, and, perhaps, less intellect, but who have been early trained to apply to practical use what science they have.

Iron ship building has had almost its entire growth within the last forty years.

In the spring of 1845, I visited a small iron ship yard, then quite a new thing, at Birkenhead, on the south side of the Mersey. The proprietor, in his green flannel roundabout, showed his modest establishment, and explained some of the processes. That proprietor became afterwards well known to the world as Sir John Laird, the great iron ship builder, and especially to this country as the builder of the *Alabama.* The operations of that enterprising craft came near involving us and our cousins across the water in a very serious conflict. This was averted by the moral courage and enlightened patriotism of Grant and Hamilton Fish on this side, and Gladstone and Clarendon on the other, who, not having the fear of demagogues before their eyes, agreed upon arbitration instead of war. All honor to the statesmen who took this great step in Christian civilization.

They were just beginning to build the first dock wall on the red sandstone bed rock of the Mersey ; now they have 159 acres of dock room enclosed. Then Birkenhead was a small village ; now it has more than 100,000 inhabitants.

America is not the only country that moves.

Mr. Chanute, in his annual address, two years ago, spoke of the first propeller boat used in America. That propeller fell into my hands ; and I towed the first fleet of boats ever towed by a propeller tug on this side of the Atlantic, from Philadelphia to Bordentown, in October, 1839. Now, our harbors are full of them. The first propellers ever built in this country, and, as far as I know, the first iron hulls, were the *Anthracite* and the *Black Diamond,* built on the plans of Captain Ericsson, and employed in carrying coal through the Delaware and Raritan Canal. The first sea-going propeller built in this country was the frigate *Princeton,* built on Captain Ericsson's designs, under the direction of Captain Stockton. It was a full rigged sailing ship, the intention being to use steam only as auxiliary.

It should not be forgotten that John Stevens, almost eighty years ago, built a small propeller boat, with two propellers, or "circular sculls," as he called them, and ran it about the harbor of New York. It is wonderful how near his blades approach the angle which experience has

shown to be best. He used a small locomotive boiler, as it would now be called, such as was reinvented by Booth, a quarter of a century later, at Liverpool.

The rapid progress of the country, and the activity of the age, are more strikingly shown by the records of the Post Office Department, than by the increase of population—from three to fifty millions since the revolution—or than by any other statistics I know of. During several years of the time that Benjamin Franklin was Postmaster General, he personally kept the whole accounts of the department, and all in one small book, and settled with the postmasters and mail carriers. There were then about, perhaps, twenty or thirty dead letters a year, now there are four millions. It now takes eight clerks constantly employed to open them, and I remember that it takes fifty clerks to take charge of one class of them. Franklin kept one small book, which lasted three years, now there are 150 or 200 books, each half a dozen times as large, filled each year, Then the work was done by Franklin for $600 a year, now by 700 clerks, for, perhaps, a million a year.

Within my memory, some of the sciences with which engineers have specially to do, have grown from infancy into at least adolescence.

For example, geology was a collection of interesting but isolated facts, and unverified theories, now it is a science. It used to be considered terribly heterodox, and a young man who cared to stand well with good people found it safest to say nothing about it. To read geology was next to reading Tom Paine. A learned and excellent divine once confidently informed me that all the supposed plants and animals found in the rocks were merely stones that happened to come out in that shape. Now geology has an important connection with the instruction in theological seminaries.

Business and population depend on geology. A geological map of England enables one to locate its occupations and the denser populations. An outcrop of gneiss, extending southwest from New York, forms the limit of tide in the rivers, and fixes the location of Trenton, Philadelphia, Wilmington, Baltimore, Georgetown, Richmond and other cities to the southwest.

When I studied chemistry at school, the components of compound bodies were given in percentages. For example, limestone was 48 per cent. oxygen, 12 per cent. carbon and 40 per cent. calcium. Of course, nobody could remember such proportions. Nor did it give the proximate elements of the compound. The atomatic theory, as it was called,

was known, but chemists were cautious about accepting it. They had not yet learned to distinguish between the *theory* of atoms, and the *fact* of equivalents.

One of the most surprising feats of modern science is seen in the daily predictions we have of the morrow's weather. Time was, and many of us remember back to it, when predictions were made, and by intelligent people, too, from the phases of the moon, from weather breeders, from the weather on certain anniversaries, and the like.

More than a century ago Franklin pointed out the fact that northeast storms begin at the southwest, two or three days earlier at New Orleans than at Philadelphia. Much information was afterwards accumulated, and scientific investigations were from time to time made by many able men. About forty years ago Prof. Espy of Philadelphia announced his theory, that rain is caused by the rarefaction and consequent upper movement of the mixed air and vapor into a colder region, where the vapor is condensed and falls into rain, and that this rarefaction produced by the heated surface of the earth, or by fire or otherwise, causes the denser air to flow in from every side, so that the wind blows towards the rain. All this has been since verified. But this sanguine philosopher did not get the credit he really deserved, but drew upon himself the ridicule of the world, by claiming for his discovery more than it could accomplish, especially by proposing to raise the Mississippi by setting fire to the woods on the Alleghany mountains, when the hygrometer showed much moisture, and so getting the upward current required to make it rain, just as it commonly rains after any great fire, or the eruption of a volcano, or a battle.

Espy visited Princeton to confer with Prof. Henry. I was present at the interview. Henry, while he thought Espy's main principle quite correct, got very much out of patience with him for several hasty conclusions from statements which, to Henry's cautious, scientific mind, did not seem at all conclusive.* After he was gone, Henry chalked out the plan which he afterwards, with the co-operation of Guyot and other able men, so successfully carried into execution, of simultaneous observations

* My attention was drawn to this subject by the conference between Espy and Henry, and while traveling in Ireland, I asked my very bright, and, on the subjects within his range, intelligent car driver which way the storms there came from? Evidently he had never thought of that subject, but, adopting on the instant a meteorological creed, answered quick as thought: "The storms, sir, come from whichever way the Lord Almighty chooses to send them."

all over the country, and a daily chart of highest and lowest pressures and other things about which my memory is less distinct. As everybody knows now, it is the traveling of these lines from west to east at an average of about 30 miles an hour, that enables the weather predictions to be made.

Our rapid progess involves the frequent undoing of what has only recently been done in the most costly manner. We have seen expensive buildings erected in the City of New York, and then in two or three years torn down to give way for something greater or different. The Alleghany Portage Railroad, of which my brother, Sylvester Welch, was chief engineer, W. Milnor Roberts being one of his assistants, was considered for some years one of the wonders of the world; the improvements in the locomotive and the increased strength of the rails afterwards enabled engines to cross the Alleghany without the inclined planes used on that road, and that splendid work, on which so much thought had been expended, was torn up. It is folly to build for the far future.

This reminds me that in a paper written in 1829, read before this society two or three years ago, Mr. Moncure Robinson estimated that the tonnage over the Alleghany mountain at that point might in time reach 30 000 tons per annum. I suppose that the tonnage now over the mountain, on the Pennsylvania railroad, exceeds six millions.

One of the bold and remarkable works of the day is the submarine sewer at Boston to carry the sewage under an arm of the harbor and across an island far to seaward. They have discovered, what unfortunately many others have not, that little is gained by emptying sewage into a harbor or into a small river, and so transferring the nuisance from one point to another, or distributing it all over.

Sanitary engineers have been contending each for his own favorite system of sewering and draining cities. Mr. Hering, in his paper read at the Convention at Montreal, impressed upon us that no one system is absolutely good or bad, but either is good when adapted to the circumstances, and bad when it is not. Municipal corporations often think that the remedy for unhealthiness is, of course, sewerage, just as some doctors in old times gave their patients calomel without regard to what was the matter with them, or what kind of constitutions they had.

One of the startling propositions of the day is to bring the waters of Lage George and the Upper Hudson by an open canal to supply the City of New York. When somebody asked Brindley what rivers were made

for, he said : "To feed navigable canals." The answer now would be : "To supply great cities with water."

Among the subjects to which the attention of the society is now especially turned are Standard Time and the Preservation of Timber. As we expect reports on these, I shall not further refer to them.

One of the most remarkable of modern implements, one whose powers seem almost miraculous, is the diamond drill, which bores into the hardest quartz conglomerate and even into chilled iron. It seems to be capable of much wider application than it has yet had.

The attachment of a car to a moving wire rope, in the way proposed by Col. Paine, without injury to the rope or risk to the car, will probably revolutionize the mode of traction in very many cases.

Within the last year or two the load on each wheel of a freight car has been increased from 5 000 lbs. to 8 000 lbs., an increase of 60 per cent. According to Dr. Dudley's observations on the Pennsylvania Railroad, an increase of 60 per cent. on a wheel made an increase in wear per million of tons of a little over 30 per cent. We may expect that this recent increase will increase the wear at least 30 per cent.; that is, the rails on a heavy traffic road that would have lasted with the old machinery 10 years, will now last 7.7 years. But with the heavier weight on a wheel, the residuary part of the rail after it is worn down to the limit of safety, must be much stronger than formerly required, in order to bear the heavier weight. Suppose the diminution of the consumable part of the rail on this account to be 20 per cent. (which would be only 4 or 5 per cent. increase on the whole rail) it reduces the duration to 6.16 years with the same traffic. But as the traffic has increased much more rapidly than was expected, it is now probable that the rails on our heavy traffic roads will not last half as long as they were expected to last three or four years ago. If a rail will last a dozen years where actually used, it would not pay to add more than about thirty per cent. to its cost to make it last two dozen years, but it would pay to add 45 per cent. to its cost to prevent its duration from coming down from a dozen to half a dozen years. Steel rails were made fifteen years ago with twice the endurance of those made now. Under the new circumstances, it is probable that it will before long be economy for roads with the heaviest traffic to pay the railmakers a price that will enable them to make rails as durable as the best ever made.

The concert of action among so many persons, and over so great distances, essential to the safe, efficient and economical operation of our

railroads, and, therefore, to the safety and cheap accommodation of the public, makes it necessary that all the operations of a great system should be in one interest and directed by one central authority. These might be governmental, but in our country, at least, experience has shown that this is absolutely inadmissible. It is in the hands of great corporations, who have vast amounts of property and armies of men under their control. In some places every third man you meet wears the button of a corporation. Whether this concentration of power is in itself good or evil, it is inevitable; and certainly a less evil than its alternative. The possession of this power carries with it grave responsibilities, especially in promoting the welfare of their employees.

Many of the best and wisest corporations recognize the duty of regarding their employees not merely as parts of a vast machine, but also as men. Saying nothing now of any higher considerations, they know that if they show a proper interest in their employees, their employees will feel more interest in them; that if they provide a comfortable retreat for their train men when off duty they will not be driven to the liquor saloon for shelter; that if they give facilities for intellectual and moral improvement to the men off duty they will be better, and especially more reliable employees; and that if they give them the day of rest which God and human experience have alike declared to be necessary, they will be more efficient.

Time was when corporations had very limited powers. Now they can do pretty much everything an individual can do, and a great deal besides. So officers could do little without specific authority from the directors. According to my recollection of the minute book of the company, which in 1804 built the celebrated bridge across the Delaware at Trenton, at a cost of $180,000 (a great sum at that time), the very first resolution of the board authorized the president to purchase two shovels and a crow-bar.

The subject of uniform time for railroads is now claiming the special attention of this Society. It is of great importance, but it has been so recently and so fully placed before the Society by Mr. Fleming and others that it is only necessary to call attention to their communications.

The subject of tests for large members of metallic structures is now receiving our earnest attention. If I should speak of its necessity it would only be to repeat what is said in our memorial to Congress. I will only again call attention to one point; that is, that the process of manu-

facture of a large piece of iron or steel may be so different from that of a small piece, and therefore the quality of the two be so different, though both may be made from the same stock, that the strength of the larger cannot be inferred, but only guessed at, from the known strength of the smaller. In the larger there is more likely to be permanent opposing strains that destroy a large percentage of its strength. A remarkable instance of opposing strains, caused by treatment in manufacture, was pointed out some time ago by Colonel Paine. He found that wire coiled before it was set could not be even straightened without straining the sides beyond the limits of elasticity, and that such wire had nothing near the strength of that coiled straight. As the strength of a large metallic member of a structure cannot be tested by any machine within the reach of individual means, and as to obtain the best results requires the combined skill of several classes of experts, the aid of Congress is invoked to provide a suitable machine, and to create a board of experts whose varied skill shall plan the best experiments.

We are justly proud in this country of the system of checking baggage on our railroads. A traveler gets a check for his trunk at a hotel in Philadelphia, and gives himself no further trouble about it till he finds it at his destination, perhaps in Maine or Texas, or Oregon. It contrasts favorably with the system on the Continent of Europe, and especially with the want of system in England. But our *handling* of baggage in this country is shocking. A light English trunk will travel all over Europe without injury. Here it is likely to be destroyed in a single trip. The greater weight of the stronger trunks required here costs the railroad companies quite an appreciable amount in the course of a year, and the damage to the trunk and its contents by the rough handling it gets sometimes costs the passenger as much as his fare. And in the great majority of cases careful handling would not cost anything extra.

What is, and is to be, the effect of all the activity and progress of the present day on human welfare ?

Doubtless the preponderance of effect is good, but with many drawbacks. I will notice one :

The rapid movement of the business of the world requires an immense amount of brain work to be done by those who direct it in each business day. This is made possible by the recently introduced facilities for rapid work. Formerly, when a man wrote his own letters, he thought sentences only as fast as he could write them. Now he dictates three or

four sentences to his stenographer in the time he would have been writing one, and so performs three or four times as much brain work per minute, as he would if he wrote himself. He does not go out of his office to confer with a man at some other office, but sits still and telephones him. When the railroad officer travels on his own road he does not chat with his friends in the public car, but goes in his office car, with his stenographer, clerks and table covered with papers. When a man goes home from his office he does not take the time to walk, but works on till the last moment, then goes on the Elevated Railroad. The brain gets no rest, as it would have got in old times; now constantly rushing forward, not standing in its tracks, as formerly, while the man was writing down the thought of the previous instant; now furiously at work, while formerly resting while the man was going from place to place. This kept up for six or eight hours a day must soon break a man down, and has already broken down some of our ablest men. It does not mend the matter much that next summer he can spend a few weeks at the shore, or among the mountains. A man running up hill till he is out of breath is not enabled to keep on running another hour by the prospect of rest next week. A man that runs a locomotive twenty miles an hour may run all day, but if he runs sixty miles per hour, and so his brain and eye have three times as much to do per hour, he must soon stop to rest.

Undoubtedly the progress of the age, which is so largely engineering progress, does on the whole greatly increase the welfare of mankind. By making the forces of nature do the hard work, the labors of the toiling millions are lightened many fold. The laboring man now works with brain and eye more than with muscle, and his business is now to apply some principle of science. This raises him intellectually. He now has time for improvement. Comfort and refinement, and even luxury, are brought within his reach. The forces of nature having become obedient to the will of man, they are made to produce for him not only plenty, but conveniences and luxuries formerly undreamt of. By the present facilities the races of men are brought into contact with each other. Those races are being assimilated, and the prejudices and hatreds of the past are fading away. Supreme power among men is more than ever in the hands of the most enlightened, and they are sending civilization and Christianity into the regions most benighted. The light of Heaven is beginning to shine into the Harem and the Zenana. And the time seems to be hastening when there shall universally prevail "peace on earth" and "good will towards men."